* * * COMMUNI ON RESULT REPORT (DEC. 5. 2001 [redacted]PM) * * *

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DATE: 5 December 2001

FROM: Todd V. Leone
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TO: Examiner Barbara A. Campbell
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NUMBER OF PAGES (including this transmittal sheet): 12

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RE: U.S. Patent Application
Serial No.: 09/869,544
Filing Date: 29 June 2001
For: ***Electrically Conductive Ceramics***
Inventor: Donald JAFFREY
Assignee: Ceramic Fuel Cells Limited
U.S. National Phase Filing of Australian PCT Application
Serial No.: PCT/AU99/01140
Filing Date: 23 December 1999
Priority Date: 31 December 1998
Our File No.: A-70685/DJB/MAK

MESSAGE:

This fax is in response to your telephone call of earlier today. Attached with regard to the above-referenced U.S. national phase application is a copy of the International Preliminary Examination Report dated 8 May 2001 issued by the Australian Patent Office acting as the International Preliminary Examining Authority.

Please let me know if I can be of further assistance.

IMPORTANT/CONFIDENTIAL: This facsimile communication is intended only for the use of the individual or entity to which it is addressed. The following pages contain information which may be privileged and/or confidential. If the reader of this facsimile is not the intended recipient, or the employee or agent responsible for delivering the facsimile to the intended recipient, you are hereby notified that any disclosure of the contents, or dissemination or distribution of this facsimile to others, or copying of this communication, is strictly prohibited. If you have received this communication in error, please telephone us immediately at (415) 781-1989 and return all copies of this facsimile to us by mail. We thank you for your cooperation.

2001

PATENT COOPERATION TREATY

From the:
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

DAVIES COLLISON CAVE
1 Little Collins Street
MELBOURNE VIC 3000

PCT

NOTIFICATION OF TRANSMITTAL OF INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

Date of mailing *day/month/year*	08 MAY 2001
Applicant's or agent's file reference 2245431/PHH/GH	IMPORTANT NOTIFICATION

International Application No.	International Filing Date	Priority Date
PCT/AU99/01140	23 December 1999	31 December 1998

Applicant

CERAMIC FUEL CELLS LIMITED et al

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translations to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices)(Article 39(1))(see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide

Name and mailing address of the IPEA/AU	Authorized officer
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	JAMES DZIEDZIC Telephone No. (02) 6283 2495

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 2245431/PHH/GH	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416).
International Application No. PCT/AU99/01140	International Filing Date *(day/month/year)* 23 December 1999	Priority Date *(day/month/year)* 31 December 1998

International Patent Classification (IPC) or national classification and IPC

Int. Cl. [7] C04B 35/01, 35/10, 35/12, 41/88

Applicant

CERAMIC FUEL CELLS LIMITED et al

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 3 sheets, including this cover sheet.

[X] This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of 7 sheet(s).

3. This report contains indications relating to the following items:

I	[X]	Basis of the report
II	[]	Priority
III	[]	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
IV	[]	Lack of unity of invention
V	[X]	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
VI	[]	Certain documents cited
VII	[]	Certain defects in the international application
VIII	[]	Certain observations on the international application

Date of submission of the demand	Date of completion of the report
29 June 2000	24 April 2001
Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized Officer **JAMES DZIEDZIC** Telephone No. (02) 6283 2495

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/AU99/01140

I. Basis of the report

1. With regard to the **elements** of the international application:*

- [] the international application as originally filed.
- [X] the description, pages **2, 6-10** as originally filed,
 pages , filed with the demand,
 pages **1 , 3-5** received on **29 March 2001** with the letter of **27 March 2001**
- [X] the claims, pages , as originally filed,
 pages , as amended (together with any statement) under Article 19,
 pages , filed with the demand,
 pages **11-13** received on **29 March 2001** with the letter of **27 March 2001**
- [X] the drawings, pages , as originally filed,
 pages , filed with the demand,
 pages , received on with the letter of
- [] the sequence listing part of the description:
 pages **1/3- 3/3** as originally filed
 pages , filed with the demand
 pages , received on with the letter of

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language which is:

- [] the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).
- [] the language of publication of the international application (under Rule 48.3(b)).
- [] the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, was on the basis of the sequence listing:

- [] contained in the international application in written form.
- [] filed together with the international application in computer readable form.
- [] furnished subsequently to this Authority in written form.
- [] furnished subsequently to this Authority in computer readable form.
- [] The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- [] The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

4. [] The amendments have resulted in the cancellation of:
 - [] the description, pages
 - [] the claims, Nos.
 - [] the drawings, sheets/fig.

5. [] This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

* *Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

** *Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report*

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims **1-25**	**YES**
	Claims	**NO**
Inventive step (IS)	Claims **1-25**	**YES**
	Claims	**NO**
Industrial applicability (IA)	Claims **1-25**	**YES**
	Claims	**NO**

2. Citations and explanations (Rule 70.7)

The invention is directed to an electrically conductive body of fully dense metal oxide ceramic which has been made conductive by incorporation of silver through its thickness. It is also directed to making such a body by heat treating the fully dense ceramic with a silver containing material which is placed in contact with the ceramic. In preferred forms the ceramic is alumina and/or chromia which can be present as a layer on a steel component. Documents cited and considered are:

US 3963522 (Harada)
US 5318723 (Hashemi)
US 5753574 Donaldson)
EP 256963 (Lanxide)
US 5767029 (Schuler)
JP 7-10639 (Derwent Abstract)
JP 5-41110 (Derwent Abstract)
JP 4-285085 (Derwent Abstract)
JP 3-99487 (Derwent Abstract)
JP 2-184555 (Derwent Abstract)
JP 52-32596 (Derwent Abstract)

The attorney has successfully argued that none of the citations disclose the invention as presently claimed. In particular the claims now restrict the metal oxide ceramic body to one which is "fully dense". By fully dense the material is free of pores or voids and thus essentially impermeable to oxygen at both low and high temperatures. Also the silver needs to be incorporated through the thickness of the ceramic body. Since none of the citations disclose the incorporation of silver through the thickness of the ceramic body and that the body is a fully dense ceramic, the invention is considered both novel and inventive. It is also industrially applicable.

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ELECTRICALLY CONDUCTIVE CERAMICS

The present invention relates to electrical conductivity in metal oxide ceramic materials and the creation of electrical conductivity in a normally non-conductive ceramic material. It has application in providing electrical conductivity across a layer of ceramic material. In a particular application the layer of metal oxide ceramic is adhered to a metal plate and this has special application in components of solid oxide fuel cells.

Alumina is well known as an electrical insulator and as a material which is physically and chemically stable at high temperatures. Its electrical properties are put to good use in many high temperature applications where electrical isolation is desired. However, it would be useful in many applications to have a material which has the high temperature stability of alumina while also having good electrical conductivity. It would be particularly useful if thin layers or sheets of alumina or other metal oxide ceramics could be made electrically conductive through the ceramic in selected locations.

It has now been found in one embodiment that the application of silver metal, in any of a variety of forms, to the surface of a fully dense body of metal oxide ceramic such as alumina or chromia, followed by a sustained heat treatment at temperatures in the range 750ºC-970ºC or above, can cause the ceramic to develop electrically conductivity, especially in the immediate vicinity of the silver. Alternatively, the silver may be applied to a surface of a metal substrate on which the fully dense body of metal oxide is caused to form. The conductivity so imparted to the ceramic may be a volume effect, that is, the conductivity may be imparted both laterally and through the thickness of the ceramic body. The body may be a layer, sheet, film or thin plate. However, with a body having a very small thickness, the effect may be principally through the ceramic.

Thus according to a first aspect of the present invention there is provided a body of fully dense metal oxide ceramic material which has been rendered electrically conductive through its thickness by the incorporation of silver into the material.

AMENDED SHEET
IPEA/AU

The significant feature of all heat resistant steels is the oxide layer which is formed when the steel is exposed to mildly or strongly oxidising conditions at elevated temperatures. They all form tight, adherent, dense oxide layers which prevent further oxidation of the underlying metal. These oxide layers are composed of chromium, aluminium or silicon oxides or some combination of these depending upon the composition of the steel. They are very effective in providing a built-in resistance to degradation of the underlying steel in high temperature oxidising conditions.

However, while this feature is used to great advantage in many applications, the presence of the oxide layer is highly deleterious to the use of these steels in key components of solid oxide fuel cells. These oxides, especially those of silicon and aluminium, are electrically insulating at all temperatures and this is a major problem for those fuel cell components which must act as electrical current connectors. For these heat resisting steels to be useful for electrical conducting components in fuel cells, it is imperative that the insulating effect of the oxide layer be alleviated at least in selected locations.

According to a second aspect of the invention, there is provided a component formed of steel having a surface layer of alumina, chromia or alumina-rich or chromia-rich fully dense ceramic, said layer having been rendered electrically conductive through its thickness by the incorporation of silver into the layer.

The ceramic layer protects the underlying metal from chemical interactions while the electrical conductivity provided by the silver allows it to provide electrical contact with the underlying metallic component.

The silver may be incorporated into the layer as the layer is formed on the steel or after the layer has been formed on the steel. Preferably, the layer is formed by surface oxidation of the steel, for example as in the case of a self-aluminising steel.

For fuel cell and other applications, an advantage of the present invention is that a material such as alumina which is universally renowned for its excellent thermal and electrically

insulating properties, as well as its chemical inertness, can have one of these three properties reversed without impairing the other two. The invention can provide, with alumina, a material which is still an excellent refractory material and inert in nearly all environments, but which is electrically conductive at least in selected positions. This is of special significance for various connections required in fuel cell assemblies. The effect has been found to be durable over long periods of time and over the full temperature range required for solid oxide fuel cell operation. The invention has been used to advantage to convert otherwise highly insulating alumina coated metal bipolar plates to conducting plates which can be used to collect current from operating fuel cells. The conductivity can be used as a sole means of current collection or used as a safeguard/backup in case a prime current collector mechanism fails.

The mechanism by which the silver migrates into or occurs in the metal oxide ceramic is not fully understood at this time. However, it is believed that the electrical conductivity is provided by the silver extending along grain boundaries of ceramic material. Incorporating the silver into the ceramic material can be achieved by heating the silver-containing material in contact with the ceramic material or with a substrate on which the ceramic material is formed.

According to a third aspect of the invention there is provided a method of providing electrical conductivity through a body of fully dense metal oxide ceramic material including placing a silver-containing material into contact with the ceramic material and heating the ceramic and silver-containing materials in contact with each other to at least 750ºC such that silver migrates from said silver-containing material into said layer of metal oxide ceramic material and creates electrically conductive pathways through the ceramic material.

The atmosphere in which the method is performed does not appear to be important and is conveniently air. The method is conveniently performed at atmospheric pressure.

According to a fourth aspect of the invention there is provided a method of forming a steel component with a heat-resistant and electrically conductive surface layer, said method

including selecting a steel which forms an alumina, chromia or alumina-rich or chromia-rich fully dense surface layer in oxidising atmosphere, placing a silver-containing material in contact with the surface of the steel, heating the steel and silver-containing material to at least 750ºC in an oxidising atmosphere to cause said surface layer to form on the steel and to cause silver from said silver-containing material to occur in and to create electrically conductive pathways through the layer.

Preferably the steel used in the method of the fourth aspect of the invention has an aluminium content of above 4.5 wt % .

Preferably, the heating step in the methods of the invention is to at least 800°C, more preferably at least 850°C, even more preferably at least 900°C and most preferably at least 950°C. It is believed that while the effect of the silver imparting electrical conductivity to the metal oxide ceramic material will occur at 750°C, or even less, the rate of the effect occurring is very slow at this temperature and increases with increasing temperature. The effect occurs especially quickly when the silver is in a liquid state.

The silver-containing material is preferably at least commercially pure silver, but it may be an alloy or otherwise contain selected impurities which are not severely detrimental to the effect of imparting electrical conductivity to a metal oxide ceramic material. Such impurities or alloying elements may include one or more of the noble metals, Sn, Cu and Ni.

The silver-containing material may be in sheet, mesh, paste or other appropriate form. The silver-containing material may be provided on a substrate of a type which is acceptable to the end result.

Embodiments of the invention will now be described, by way of example only, with reference to the Examples and to the accompanying drawings in which:

Figure 1 is a diagrammatic representation of an experimental arrangement used to investigate the nature of the invention;

AMENDED SHEET
IPEA/AU

CLAIMS

1. A body of fully dense metal oxide ceramic material which has been rendered electrically conductive through its thickness by the incorporation of silver into the material.

2. A body according to claim 1 wherein said thickness is no more than 1 mm.

3. A body according to claim 2 wherein said thickness is no more than 10 μm.

4. A body according to claim 1 wherein the material is alumina, chromia or alumina-rich or chromia-rich ceramic.

5. A body according to claim 1 wherein the silver extends along grain boundaries of the material.

6. A body according to claim 1 which is a layer, sheet, film or thin plate.

7. A body according to claim 6 which is a layer on a substrate.

8. A component formed of steel having a surface layer of alumina, chromia or alumina-rich or chromia-rich fully dense ceramic, said layer having been rendered electrically conductive through its thickness by the incorporation of silver into the layer.

9. A component according to claim 8 wherein the silver has been incorporated into the layer after the layer has been formed on the steel.

10. A component according to claim 8 wherein the layer has been formed by surface oxidation of the steel.

11. A component according to claim 8 which is a component for a fuel cell assembly.

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12. A component according to claim 11 which is a bipolar plate.

13. A method of providing electrical conductivity through a body of fully dense metal oxide ceramic material including placing a silver-containing material into contact with the ceramic material and heating the ceramic and silver-containing materials in contact with each other to at least 750 °C such that silver migrates from the silver-containing material into the metal oxide ceramic material and creates electrically conductive pathways through the ceramic material.

14. A method according to claim 13 wherein the silver-containing material is at least commercially pure silver.

15. A method according to claim 13 wherein the silver-containing material is an alloy of silver.

16. A method according to claim 13 wherein the silver-containing material is provided on a substrate.

17. A method according to claim 13 wherein the body of metal oxide ceramic material is provided as a layer on a substrate.

18. A method according to claim 13 wherein the metal oxide ceramic material is alumina, chromia or alumina-rich or chromia-rich ceramic.

19. A method according to claim 13 wherein the silver-containing material is in the form of a sheet, a mesh or a paste.

20. A method according to claim 13 wherein said heating is to at least 800 °C, more preferably at least 850 °C, even more preferably at least 900 °C and most preferably at least 950 °C.

AMENDED SHEET
IPEA/AU

21. A method of forming a steel component with a heat-resistant and electrically conductive surface layer, said method including selecting a steel which forms an alumina, chromia or alumina-rich or chromia-rich fully dense surface layer in oxidising atmosphere, placing a silver-containing material in contact with the surface of the steel, heating the steel and silver-containing material to at least 750°C in an oxidising atmosphere to cause said surface layer to form on the steel and to cause silver from said silver-containing material to occur in and create electrically conductive pathways through the layer.

22. A method according to claim 21 wherein the steel has an aluminum content of above 4.5 wt%.

23. A method according to claim 21 wherein the silver-containing material is at least commercially pure silver.

24. A method according to claim 21 wherein the silver-containing material is in the form of a sheet, a mesh or a paste.

25. A method according to claim 21 wherein said heating is to at least 800°C, more preferably at least 850°C, even more preferably at least 900°C and most preferably at least 950°C.

Dated this 27th day of March 2001
CERAMIC FUEL CELLS LIMITED.
By Its Patent Attorneys
DAVIES COLLISON CAVE

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTICE INFORMING THE APPLICANT OF THE COMMUNICATION OF THE INTERNATIONAL APPLICATION TO THE DESIGNATED OFFICES

(PCT Rule 47.1(c), first sentence)

To:
HUNTSMAN, Peter, H.
Davies Collison Cave
1 Little Collins Street
Melbourne, VIC 3000
AUSTRALIE

TUESDAY, 25 JUL 2000

Date of mailing (day/month/year) 13 July 2000 (13.07.00)	
Applicant's or agent's file reference 2245431/PHH	**IMPORTANT NOTICE**

International application No.	**International filing date** (day/month/year)	**Priority date** (day/month/year)
PCT/AU99/01140	23 December 1999 (23.12.99)	31 December 1998 (31.12.98)

Applicant
CERAMIC FUEL CELLS LIMITED et al

1. Notice is hereby given that the International Bureau has communicated, as provided in Article 20, the international application to the following designated Offices on the date indicated above as the date of mailing of this Notice:
 AU,CN,JP,KP,KR,US

 In accordance with Rule 47.1(c), third sentence, those Offices will accept the present Notice as conclusive evidence that the communication of the international application has duly taken place on the date of mailing indicated above and no copy of the international application is required to be furnished by the applicant to the designated Office(s).

2. The following designated Offices have waived the requirement for such a communication at this time:
 AE,AL,AM,AP,AT,AZ,BA,BB,BG,BR,BY,CA,CH,CR,CU,CZ,DE,DK,DM,EA,EE,EP,ES,FI,GB,GD,GE,
 GH,GM,HR,HU,ID,IL,IN,IS,KE,KG,KZ,LC,LK,LR,LS,LT,LU,LV,MA,MD,MG,MK,MN,MW,MX,NO,NZ,
 OA,PL,PT,RO,RU,SD,SE,SG,SI,SK,SL,TJ,TM,TR,TT,TZ,UA,UG,UZ,VN,YU,ZA,ZW
 The communication will be made to those Offices only upon their request. Furthermore, those Offices do not require the applicant to furnish a copy of the international application (Rule 49.1(a-bis)).

3. Enclosed with this Notice is a copy of the international application as published by the International Bureau on
 13 July 2000 (13.07.00) under No. WO 00/40520

REMINDER REGARDING CHAPTER II (Article 31(2)(a) and Rule 54.2)

If the applicant wishes to postpone entry into the national phase until 30 months (or later in some Offices) from the priority date, **a demand for international preliminary examination** must be filed with the competent International Preliminary Examining Authority before the expiration of 19 months from the priority date.

It is the applicant's sole responsibility to monitor the 19-month time limit.

Note that only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination.

REMINDER REGARDING ENTRY INTO THE NATIONAL PHASE (Article 22 or 39(1))

If the applicant wishes to proceed with the international application in the **national phase**, he must, within 20 months or 30 months, or later in some Offices, perform the acts referred to therein before each designated or elected Office.

For further important information on the time limits and acts to be performed for entering the national phase, see the Annex to Form PCT/IB/301 (Notification of Receipt of Record Copy) and Volume II of the PCT Applicant's Guide.

The International Bureau of WIPO
34, ch min des Col mbettes
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 740.14.35

Authorized officer
J. Zahra

Telephone No. (41-22) 338.83.38